MODIS VIIRS 2018 Science Team Meeting

How is the Barrow tundra in Alaska responding to climate change?

Qingyuan Zhang[1,2], K.F. Huemmrich[3,2], E.M. Middleton[2], Yujie Wang[3,2], Mark Carrol[4,2], Alexei Lyapustin[2], D.R. Landis[5,2]

[1]Universities Space Research Association, [2]NASA Goddard Space Flight Center,[3]University of Maryland Baltimore County, [4]Science Systems and Applications Inc.,[5]Global Science and Tech, Inc.

Introduction

How are high latitude ecosystems responding to high rates of climate change? Previous work has examined change in the normalized difference vegetation index (NDVI). However, NDVI for high latitude ecosystems is affected by a number of factors including varying amounts of bare ground cover, surface water, and snow, and relatively large proportions of non-green materials (e.g., standing dead vegetation) in the canopy. We have developed a coupled leaf, vegetation, soil, surface water body, and snow radiative transfer model (LVS3). The LVS3 model provides physically-based $fAPAR_{chl}$, the fractional absorption of photosynthetically active radiation (PAR) by chlorophyll, a descriptor of photosynthetic potential. The LVS3 model also provides cover fractions of vegetation (VGCF), soil (SOILCF), snow (SNOWCF) and surface water body (WaterBodyCF).

We aim to 1] explore how vegetation, soil, snow and surface water affect spectral indices--- including the NDVI, the enhanced vegetation index (EVI), near-infrared vegetation index (NIR_v) and the normalized difference snow index (NDSI); and 2] examine changes in (bio)physical variables and spectral empirical indices in response to recent climate changesin high latitude areas.

Study Area and Methods

We studied a tundra area around Utqiagvik (Barrow), AK (Fig. 1). Biophysical variables VGCF, *f*APAR by canopy ($fAPAR_{canopy}$), $fAPAR_{chl}$, *f*APAR by non-chlorophyll components of canopy ($fAPAR_{non\text{-}chl}$), and physical variables SOILCF, SNOWCF and WaterBodyCF are retrieved with the advanced model LVS3 and surface reflectance images. NDVI, EVI, EVI2, NIR_v and NDSI are computed with the same surface reflectance images.

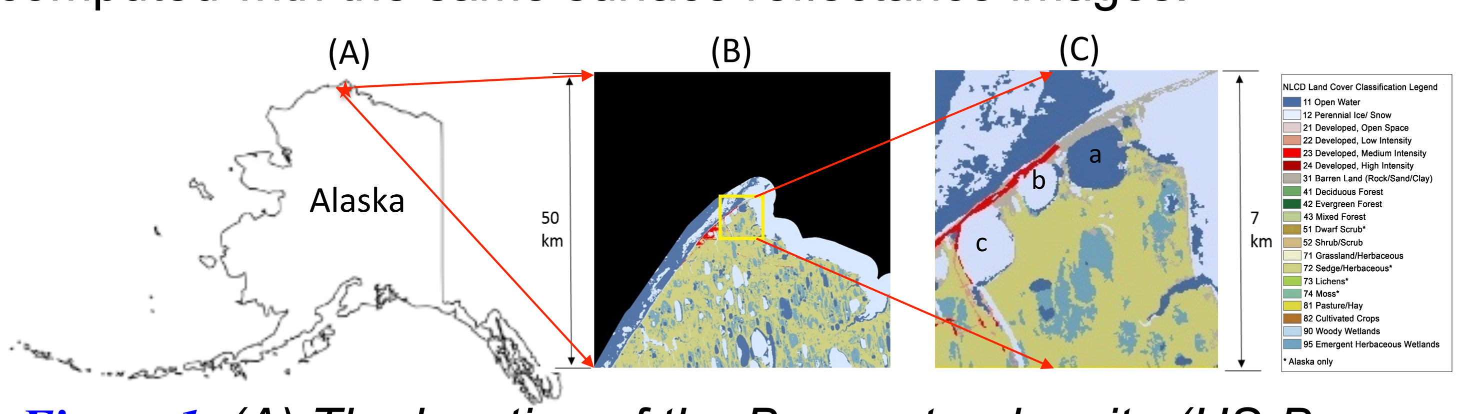

Figure 1 (A) The location of the Barrow tundra site (US-Brw: 71.32°N, 156.61°W) in Alaska; (B)the 50 × 50 km² NLCD (2001) classification map surrounding the US-Brw site; (C) the 7 × 7 km² NLCD (2001) classification map surrounding the US-Brw site where (a) is the North Salt Lagoon, (b) is the Imikpuk Lake, and (c) is the Middle Salt Lagoon.

Results and Discussions

We acquired a Hyperion image that encompassed the Barrow region on June 20, 2013 (DOY 171). Fig. 2(A) shows the true color image. Fig. 2(B) – (L) manifests biophysical variables VGCF, $fAPAR_{canopy}$, $fAPAR_{chl}$ and $fAPAR_{non\text{-}chl}$, physical variables SOILCF, SNOWCF, and WaterBodyCF, and indices NDSI, NDVI, EVI and NIR_v. Fig. 2 also shows that there are significant differences between NDVI and $fAPAR_{chl}$ for this region. Fig. 3 presents how vegetation, soil, snow and surface water quantitatively affect the indices NDVI, EVI, NIR_v and NDSI. These indices can't easily distinguish between vegetation, soil, snow and surface water. SNOWCF provides more details of snowmelt than the NOAA ESRL approach (Fig. 4). Fig. 5 – 6 illuminate multiyear changes in multiple variables for this tundra region. These changes appear to be completely reversible.

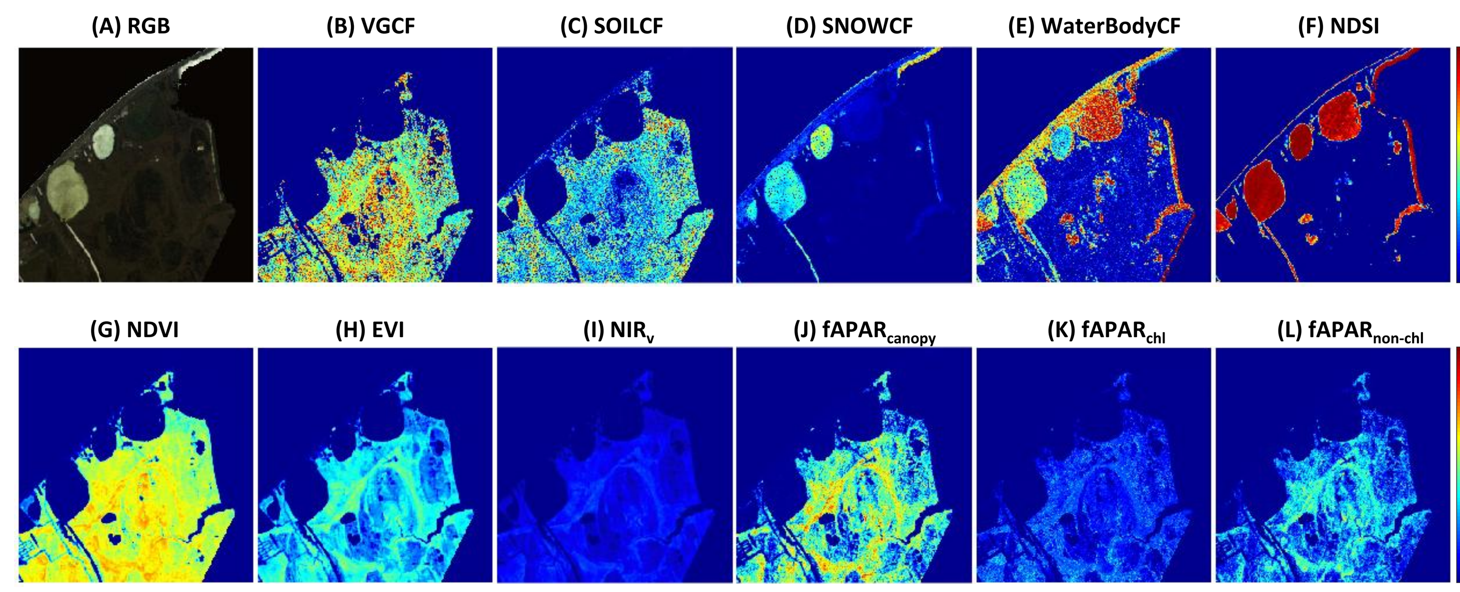

Figure 2 The Arctic tundra at Barrow in Alaska: (A) Hyperion true color image on DOY 171 of 2013; and maps of (B) VGCF; (C) SOILCF; (D) SNOWCF; (E) WaterBodyCF; (F) NDSI; (G) NDVI; (H) EVI; (I) NIR_v; (J) $fAPAR_{canopy}$; (K) $fAPAR_{chl}$ and (L) $fAPAR_{non\text{-}chl}$. (B) – (E) describe cover classes and (G) – (L) describe vegetation properties. Note that values of empirical indices NDSI, NDVI, EVI and NIR_v that fall out of the ranges of the legends are not shown.

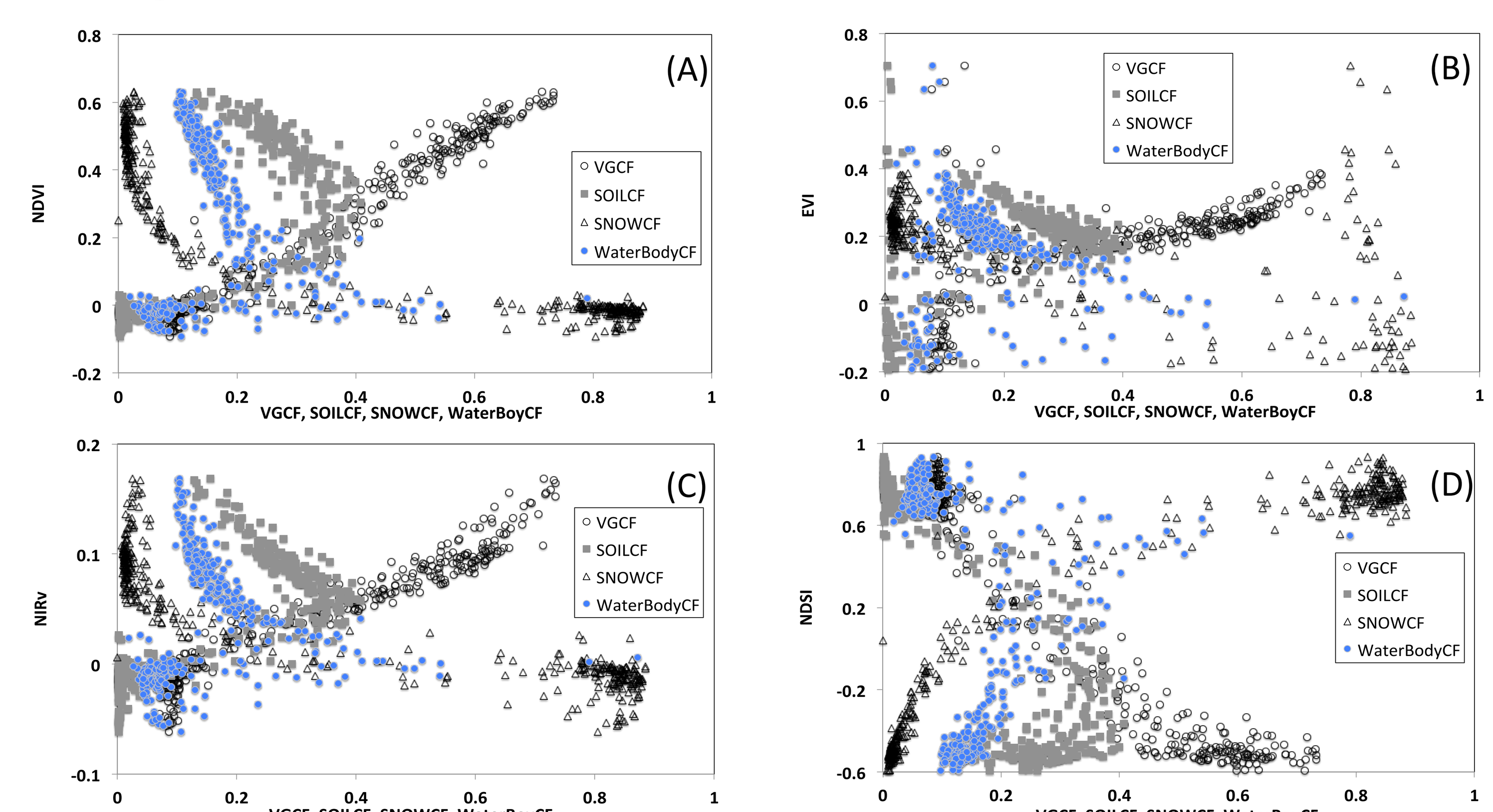

Figure 3 Relationships between empirical indices and physical variables VGCF, SOILCF, SNOWCF and WaterBodyCF for the study area during 2001 – 2014: (A) NDVI; (B) EVI; (C) NIRv; and (D) NDSI.

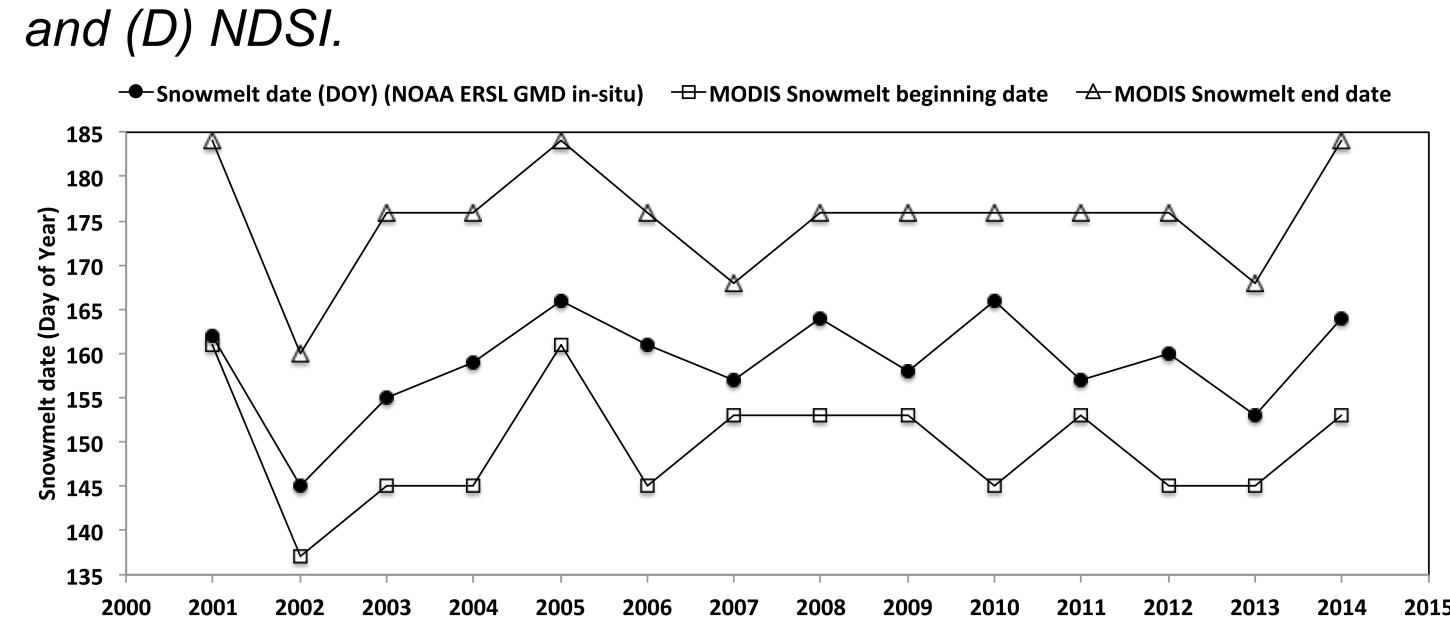

Figure 4 Time series of snowmelt dates determined by NOAA ERSL (Stone et al., 2002) and snowmelt dates determined with SNOWCF for the study area of the US-Brw site in 2001 – 2014.

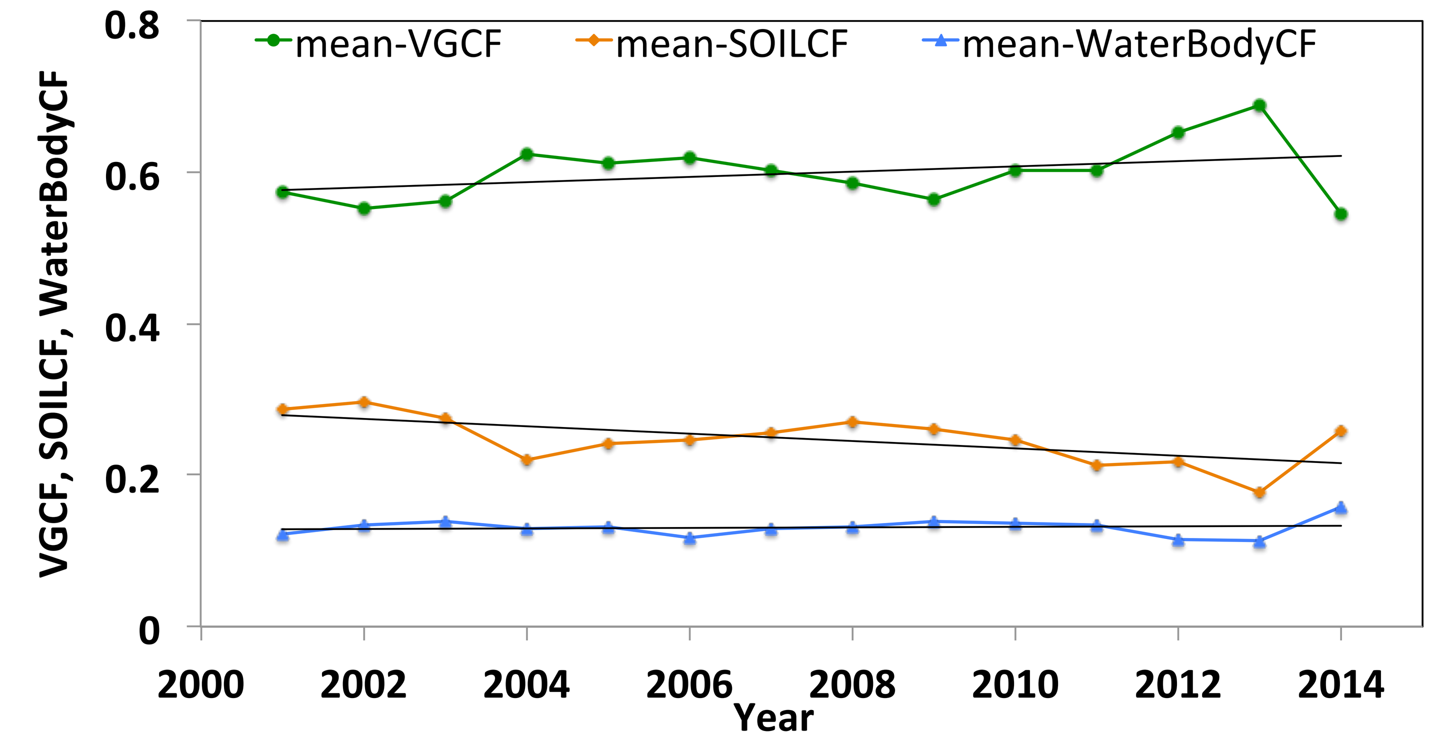

Figure 5 Time series of summertime averages (DOY 200 - 248) of VGCF, SOILCF and WaterBodyCF during 2001 – 2014.

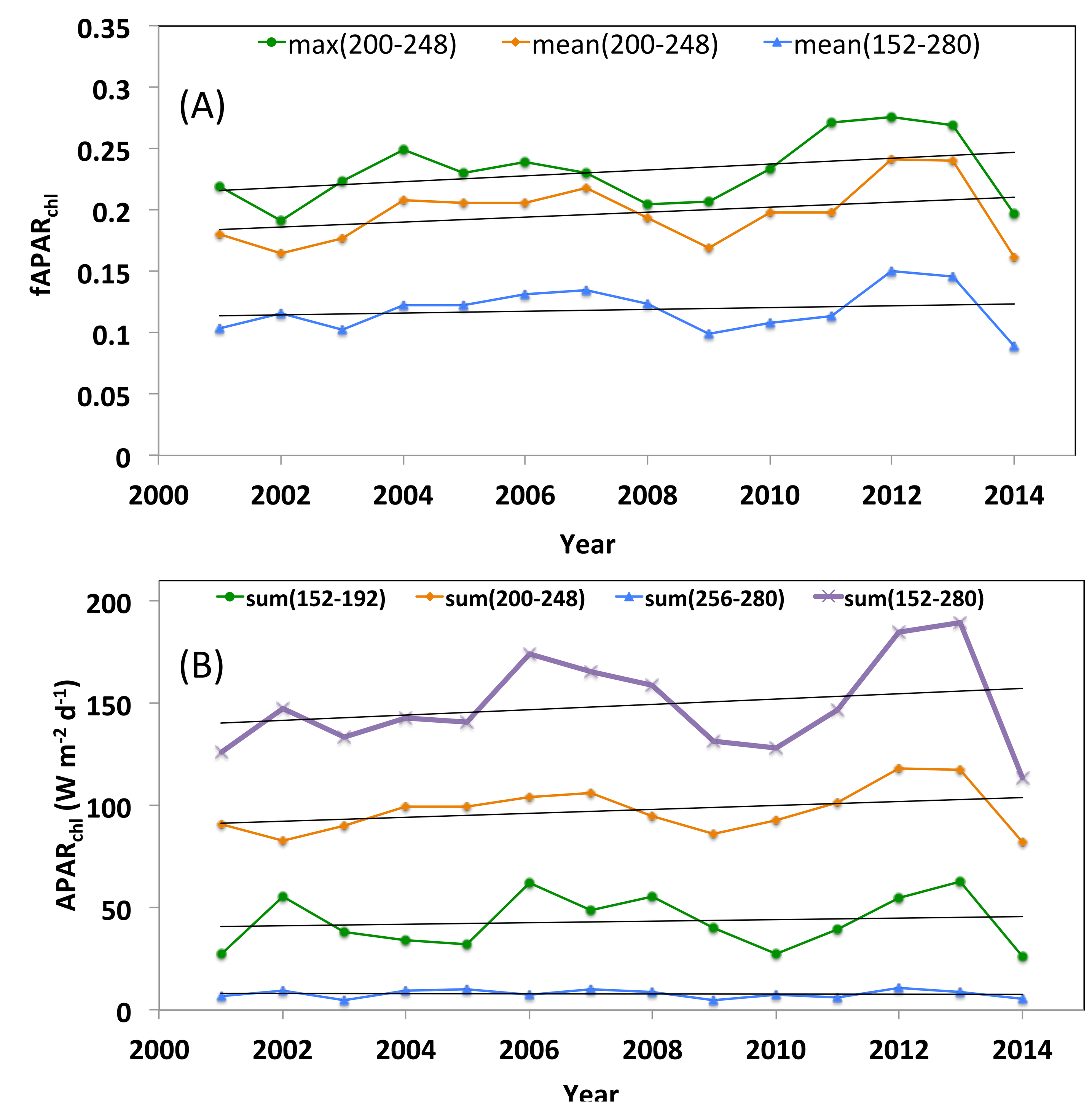

Figure 6 (A) seasonal averages of $fAPAR_{chl}$ for green-up (DOY 152 – 192), summer (DOY 200 – 248), and senescence (DOY 256 – 280) during 2001 – 2014; (B) sums of $APAR_{chl}$ (=$fAPAR_{chl} \times PAR_{in}$) in units of W m^{-2} d^{-1} for green-up, summer, and senescence, along with the sum over the entire growing season (DOY 152 – 280).

Conclusions

The NDVI, EVI, NIR_v and NDSI are all affected by vegetation, soil, snow, and surface water. Only the $fAPAR_{chl}$ parameter accurately describes the chl-containing vegetation contributing to photosynthesis. General trends over the 14-year study period show increases for VGCF, $fAPAR_{chl}$ and subsets (except for senescence periods). However, due to the large year-to-year changes over the study period, while responding to warming conditions this tundra ecosystem has not yet reached a tipping point and can still return to its original state.